N90-10156

LASER-POWERED LUNAR BASE

R. Costen, D. Humes — Nuclear Reactor Reference Mission

G. Walker — Laser-to-Electric Lunar Base Converter

M. Williams, R. De Young — Diode Array and Iodine Lasers

R. De Young — Mission Payoff Summary

Introduction

The objective ~~of this stud~~y was to compare a nuclear reactor-driven Sterling engine lunar base power source to a laser-to-electric converter with orbiting laser power station, each providing 1 MW of electricity to the lunar base. The comparison was made on the basis of total mass required in low-Earth-orbit for each system. This total mass includes transportation mass required to place systems in low-lunar orbit or on the lunar surface.

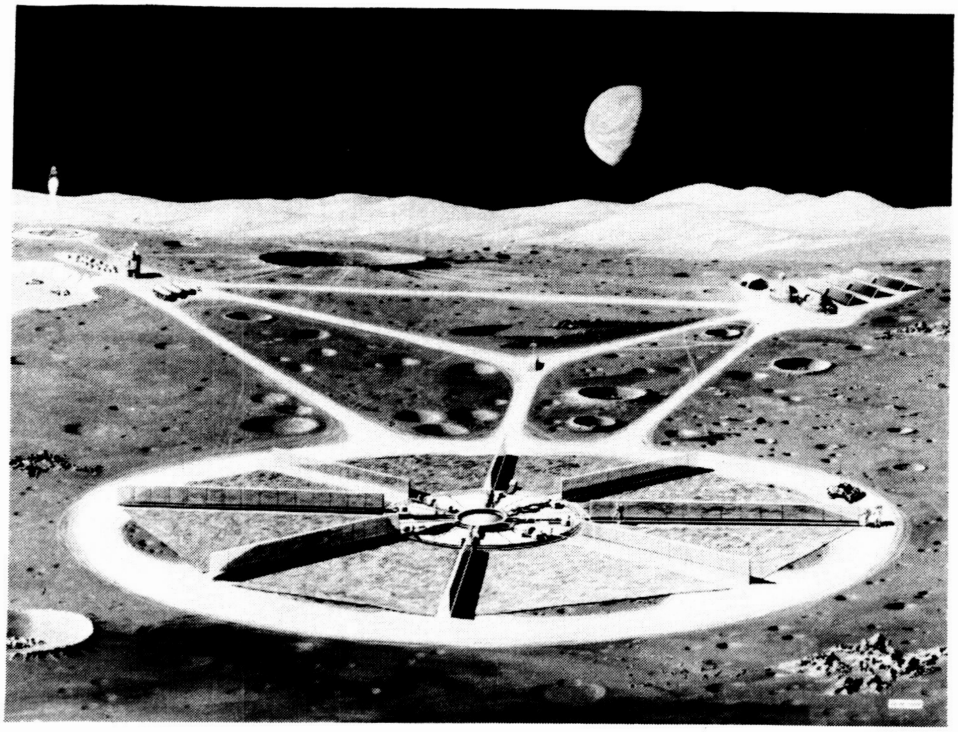
The nuclear reactor with Sterling engines is considered the reference mission for lunar base power and is described first. The details of the laser-to-electric converter and mass are discussed. The next two solar-driven high-power laser concepts, the diode array laser or the iodine laser system, are discussed with associated masses in low-lunar-orbit. Finally, the payoff for laser-power beaming is summarized.

REFERENCE MISSION - NUCLEAR REACTOR POWER FOR LUNAR BASE

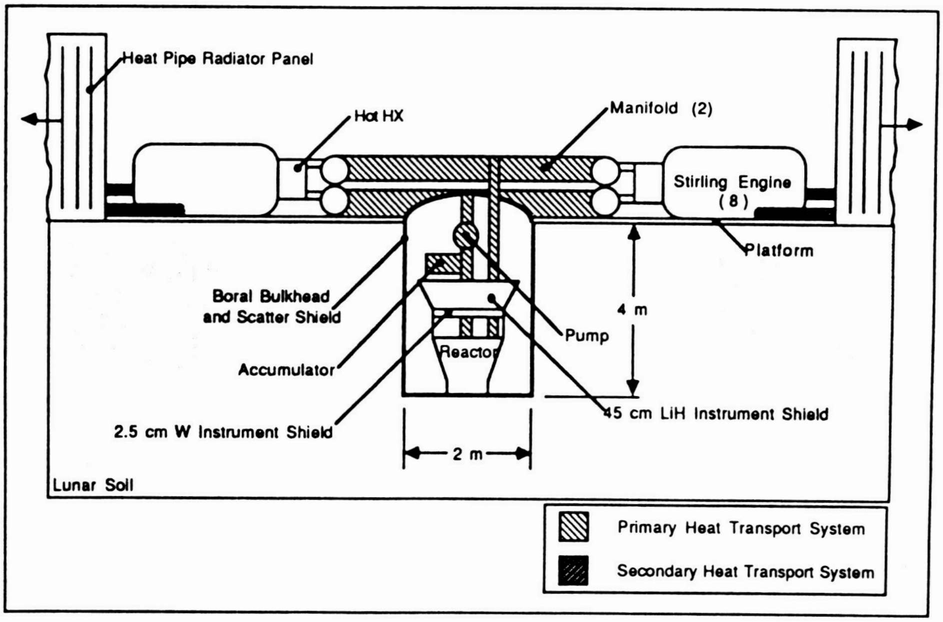
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Nuclear Power System Layout



POWER AND MASS

Power Rating:		
Reactor Thermal Power		2500 kWt
Electrical Power Output		825 kWe
Nuclear Power Plant Mass:		
Reactor/Instrument Shielding	3489 kg	
Converter	6876 kg	
Power Conditioning	2567 kg	
Radiator	7072 kg	
		20,004 kg
Vehicle and Propellant Mass (LEO to Lunar Surface)		83,017 kg
Total Mass in LEO		103,021 kg

ADDITIONAL CONSIDERATIONS

Advantages of Nuclear Power for Lunar Base:

- Continuous Power (7 Years)
- Existing Technology
  - SP-100 Reactor (Scaled Up)
  - Stirling Engines

Disadvantages:

- Fixed and Permanent Location on Lunar Surface
- Radiation Safety
  - Location Away from Habitat
    - Impractical for Heating Habitat with WasteThermal Energy
    - Long Electric Cables
  - Maintenance Requires Robotics Technology
    - No Containment Vessel
    - Micrometeoroids
    - Embrittlement

REFERENCE DOCUMENTS

Nuclear Power Plant Configuration and Specifications:

Office of Exploration (Code Z) Case Study 4

NASA TM 4075, October 1988

Masses of Power Plant Components:

"SP-100 Power System Conceptual Design for Lunar Base Applications," by Lee S. Mason and Harvey S. Bloomfield (NASA Lewis Research Center) and Donald C. Hainley (Sverdrup Technology, Inc.), Transactions of the Sixth Symposium on Space Nuclear Power Systems, Albuquerque, NM, January 8-12, 1989, pp. 9-12.

Mases of OTV, Lunar Lander, and Propellant:

"Conceptual Analysis of a Lunar Base Transportation System," by Tevor D. Hoy and Lloyd B. Johnson, III, (USAF), Mark B. Persons (George Washington University), and Robert L. Wright (NASA Langley Research Center), Paper No. LBS-88-233, Lunar Bases & Space Activities in the 21st Century, Houston, TX, April 5-7, 1988.

LASER-TO-ELECTRIC LUNAR BASE CONVERTER

ND2 10491

Gilbert H. Walker

PHOTOVOLTAIC CONVERSION OF LASER TO ELECTRICAL POWER

- HIGH INTENSITY
- BANDGAP MATCH
- SELECTION OF SEMICONDUCTOR
- TYPES OF PHOTOVOLTAIC CONVERTERS
- MAXIMUM EFFICIENCY

CONSIDERATIONS FOR PHOTOVOLTAIC CONVERTERS

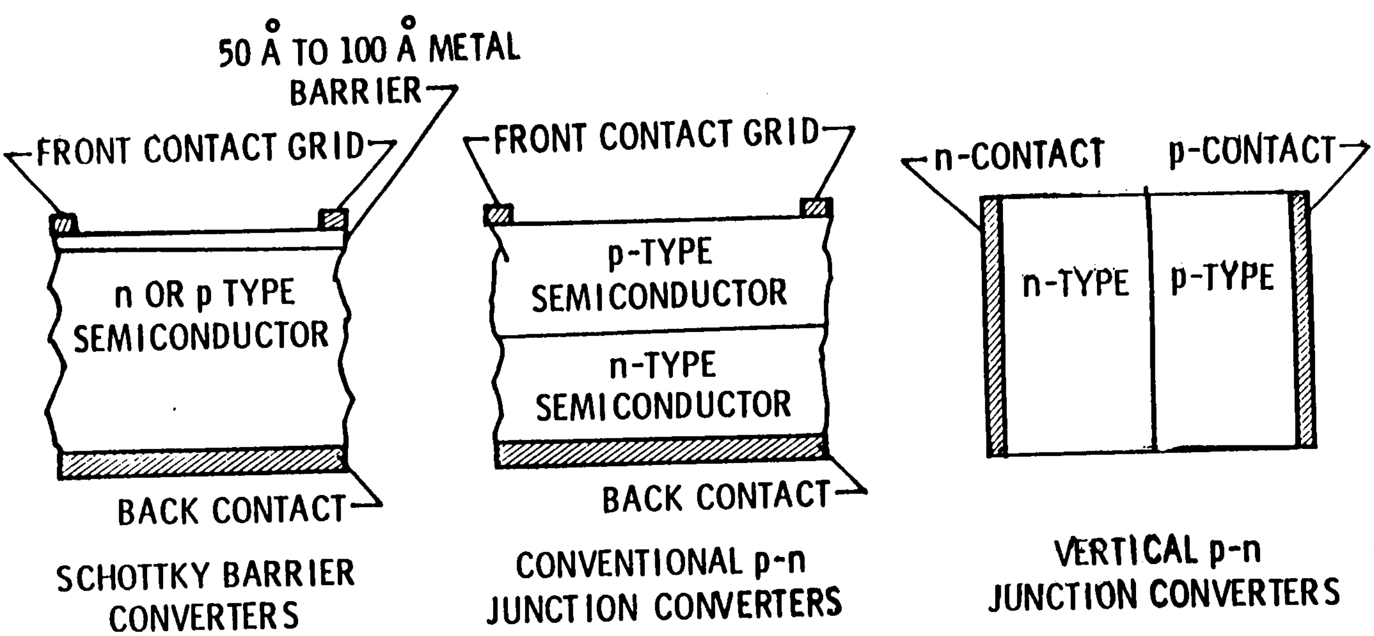
- ENERGY OF PHOTONS
- BANDGAP ENERGY OF SEMICONDUCTOR
- INCIDENT POWER DENSITY OF PHOTONS
- POWER CONVERSION EFFICIENCY
- CURRENT DENSITY
- SERIES RESISTANCE
- TYPE OF CONVERTER

PHOTOVOLTAIC CONVERTERS
Requirements

Convert iodine (1.315 µm) or diode (0.85 µm) laser radiation to electricity

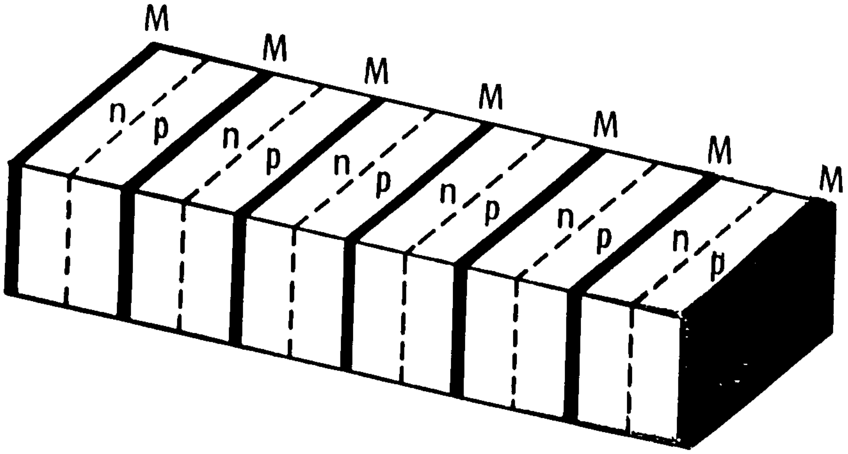
Converter output fixed at 1 MWe

TYPES OF PHOTOVOLTAIC CONVERTERS



SERIES-CONNECTED, VERTICAL-MULTIJUNCTION PHOTOVOLTAIC CONVERTER

M - metal
n - n-type semiconductor
p - p-type semiconductor



OPTIMUM PHOTOVOLTAIC CONVERTERS

For iodine laser (1.315μm) radiation:

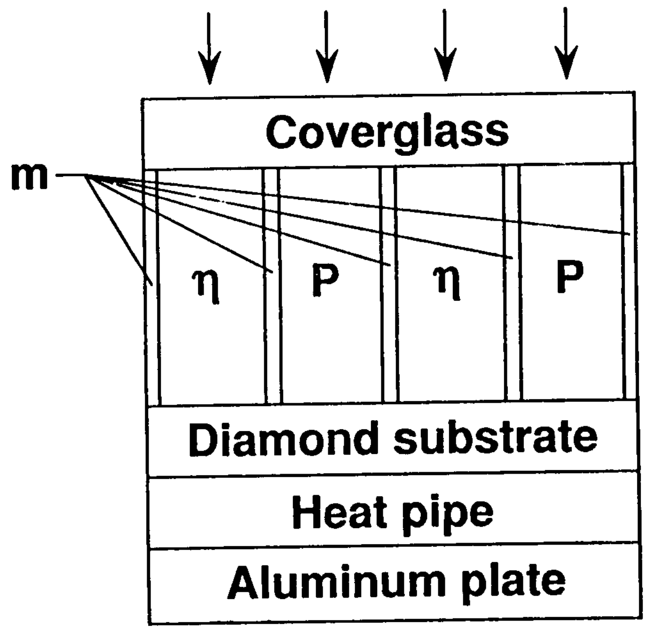
Use $Ga_{.53}In_{.47}As$

For diode array laser (0.85μm) radiation:

Use $Ga_{.971}Al_{.029}As$

SCHEMATIC DIAGRAM OF CONVERTER

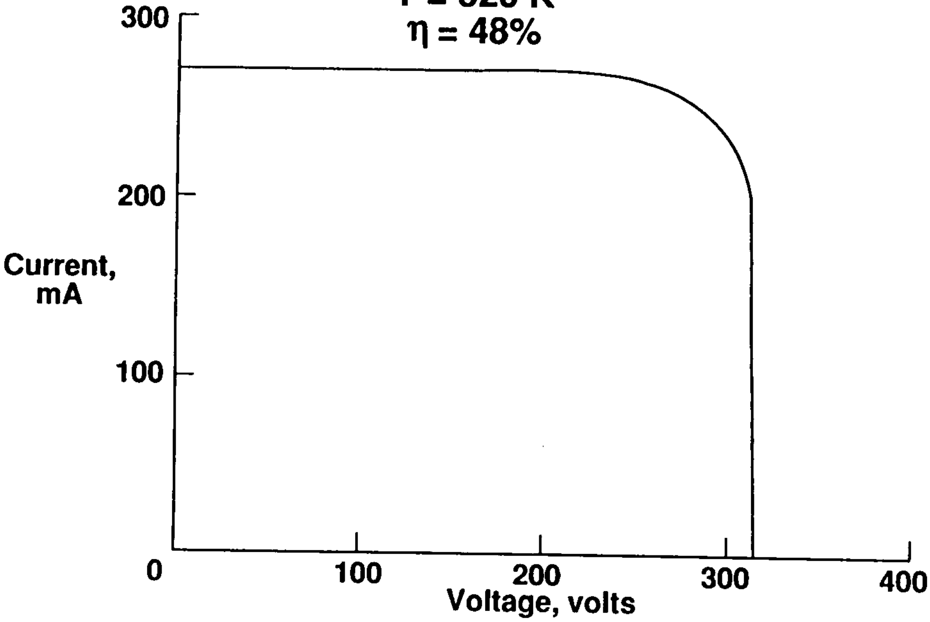
LASER BEAM



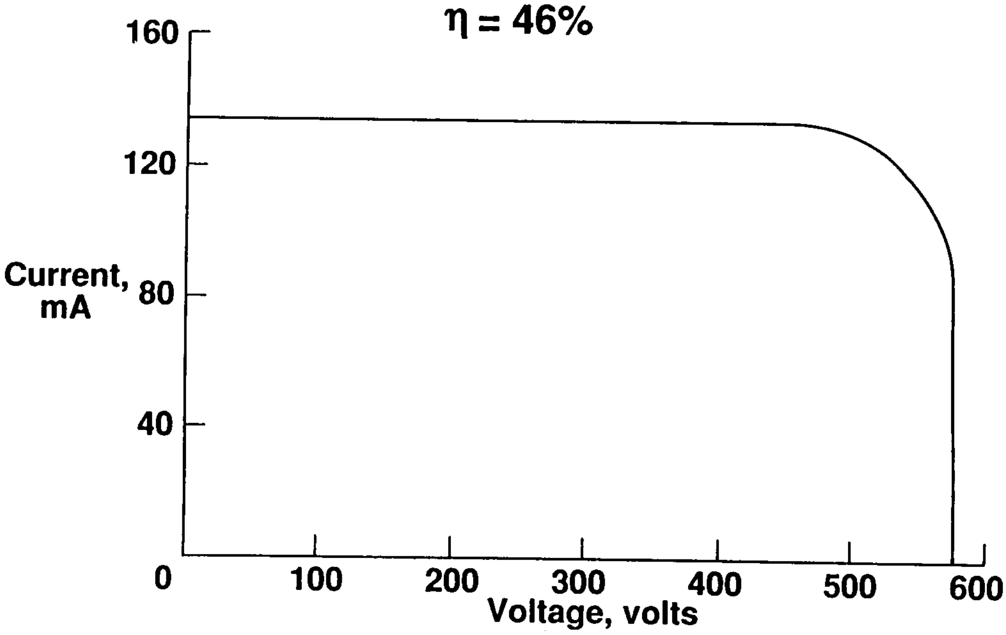
CHARACTERISTICS OF $Ga_{.971}In_{.029}As$ AND $Ga_{.53}Al_{.47}As$ converter

Number of junctions	500
Temperature	300 K
Recombination velocity	1×10^{4} cm sec^{-1}
Laser wavelength	1.315 μm, 0.85 μm
Converter thickness	3×10^{-3} cm
Converter width	3×10^{-4} cm
Converter length	1 cm
Width of p-region	2.5×10^{-4} cm^{-3}
Carrier concentration	1×10^{17}cm
Reflection coefficient	0.05

CURRENT - VOLTAGE CHARACTERISTICS OF A $Ga_{.53}In_{.47}As$ IODINE LASER CONVERTER
T = 320 K
η = 48%



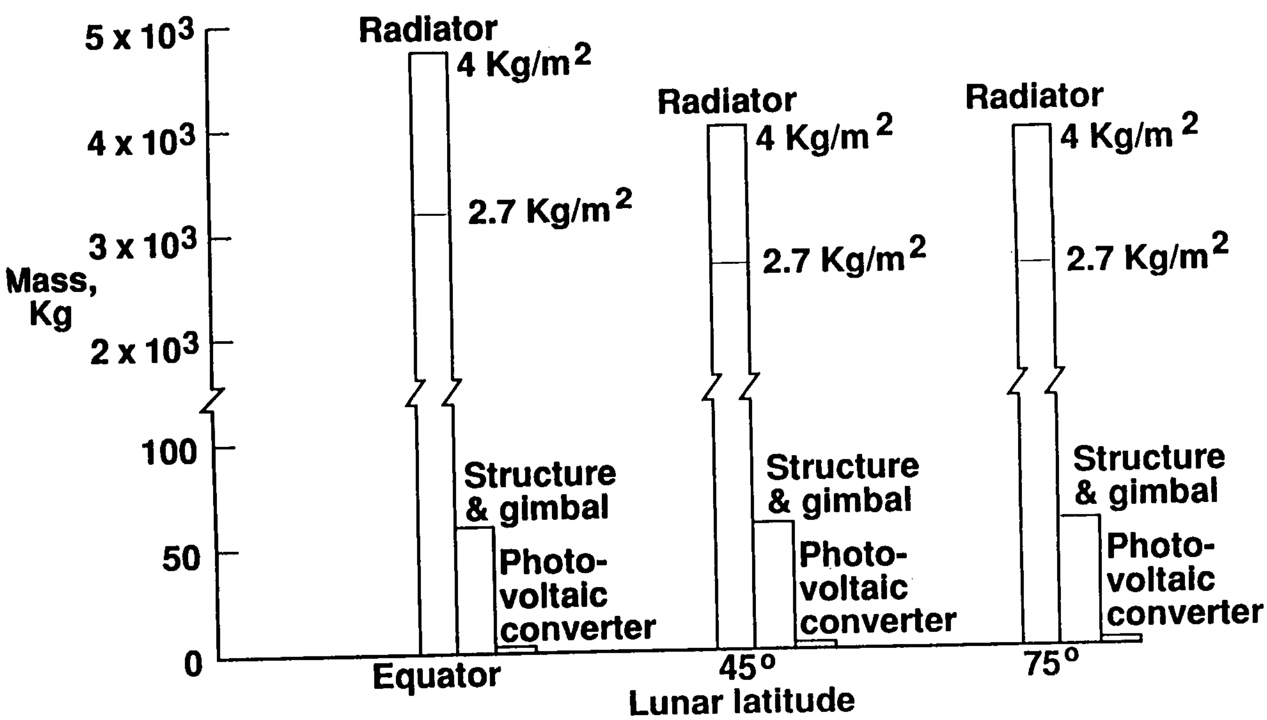
CURRENT - VOLTAGE CHARACTERISTICS OF A $Ga_{.971}Al_{.029}As$ DIODE LASER CONVERTER
T = 320 K
η = 46%



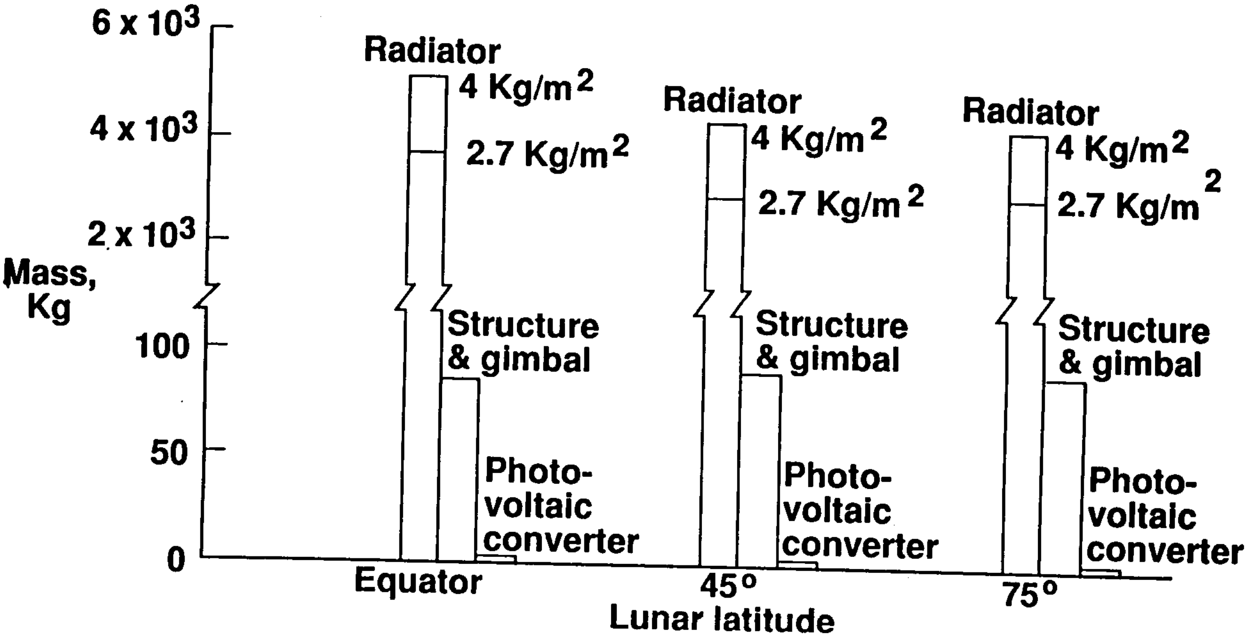
MASS BREAKDOWN FOR CONVERTER SYSTEM

Converter	0.85 μm	1.315 μm
A. Semiconductor	6.59×10^{-2} Kg	6.88×10^{-2} Kg
B. Coverglass	3.31×10^{-1} Kg	3.31×10^{-1} Kg
C. Diamond substrate	4.35 Kg	4.35 Kg
D. Supporting blanket	3.38 Kg	3.38 Kg
Total mass converter	8.12 Kg	8.13 Kg

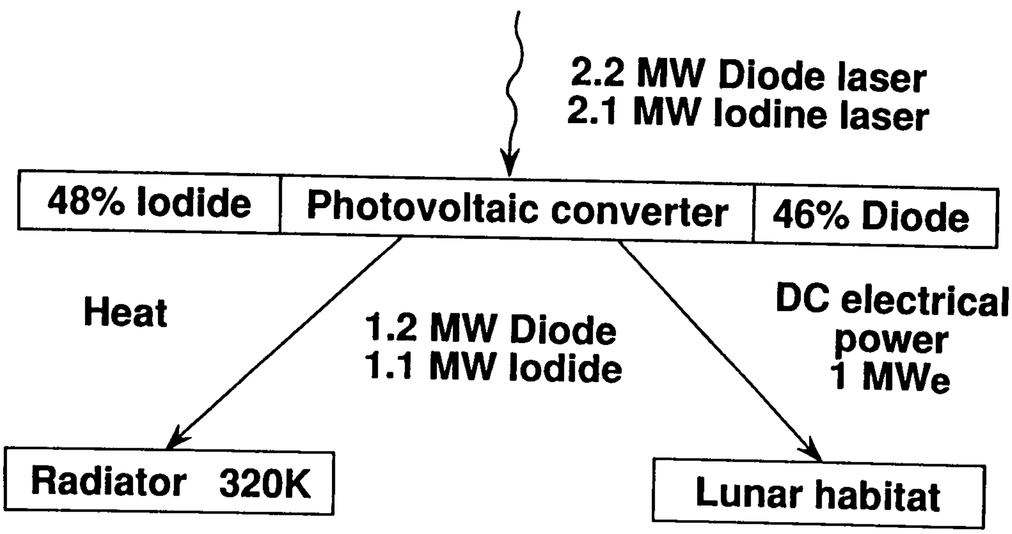
MASS OF IODINE LASER-PHOTOVOLTAIC CONVERTER COMPONENTS



MASS OF DIODE LASER-PHOTOVOLTAIC CONVERTER COMPONENTS



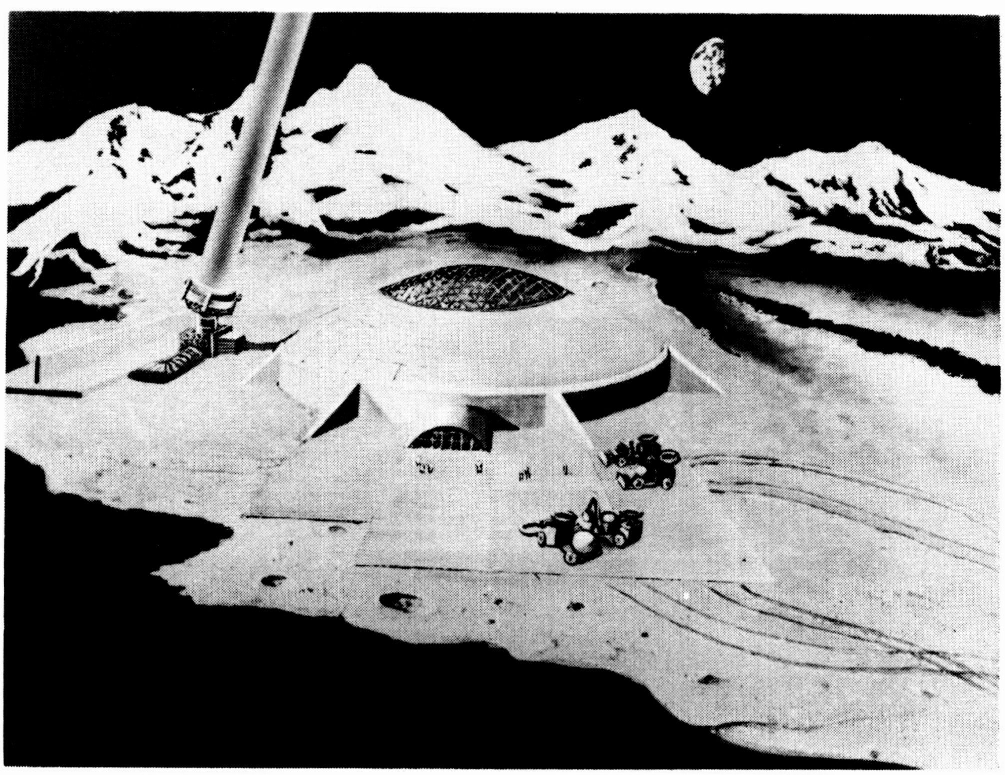
BLOCK DIAGRAM OF LASER-TO-ELECTRIC CONVERSION



LEO CONVERTER MASS SUMMARY

	IODINE LASER CONVERTER (1.3 μm)	DIODE LASER CONVERTER (0.85 μm)
Converter Mass (Equator)	7.11×10^3 Kg	7.70×10^3 Kg
OTV and Fuel	29.4×10^3 Kg	31.9×10^3 Kg
Total LEO Mass	36.6×10^3 Kg	39.7×10^3 Kg

LASER POWERED LUNAR BASE



ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

SUMMARY

- Converter mass on lunar surface - 7000 kg.
- Radiator dominant mass component.
- Transportation costs to lunar surface - 30,000 kg.
- Converter approaching 50% laser-to-electric feasible.